TECHNOLOGY REVIEW ON PV/THERMAL CONCEPTS

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Abstract - Ecofys energy and environment has performed a technology survey on hybrid PV/Th systems. This survey was performed in a joint research with the Eindhoven University of Technology (EUT) and the Dutch centre for applied Physics (TNO) and funded by Novem. The research consisted of two parts: a literature survey and the development and assessment of a evaluation method on PV/Th systems. The major findings of this study will be presented here, with a strong emphasis on the market assessment.
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1. INTRODUCTION

Solar thermal collectors are commercially widespread in many European countries. Simultaneously, building integrated photovoltaic (PV) systems are merging to market introduction. At the moment, each system is installed, separately, on the same roof. This leads to the logical question to combine both systems in one 'hybrid' pv / solar thermal system. Such a hybrid system will thus generate both heat and power (electricity). Advantages in combining the two products concern the:

- Reduced production costs
- Reduced installation and mounting costs
- Reduced amount of roof area
- Enhanced uniform architectural appearance

To investigate the renewed interest in PV/Th systems, Ecofys has performed, together with the Eindhoven University of Technology and the Dutch centre for applied Physics (TNO), a literature survey and developed an evaluation method to compare the various PV/Th developments [1].

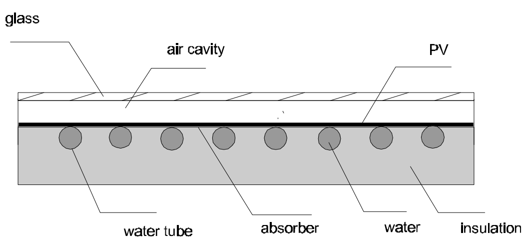

Figure 1: Example of PV/Th water collector.

2. LITERATURE SURVEY

The literature survey showed that, over the past 20 years, various companies and institutes investigated the possibilities of hybrid PV/Th products, utilising water or air as heat transferring medium. Most of this research concentrated on analytical and experimental research and developments. Continued product developments towards demonstration, or even market introduction products are rare (apart from a few exceptions like e.g. the Spectrum collector of Solarwerk [2]). On the level of PV/Th systems this situation is reversed. During the past 4 to 5 years various hybrid roof and facade systems have been demonstrated, without much fundamental research being reported.

Both the hybrid PV/Th product and system developments are mainly developed from technical interest and less from market interests. This phenomenon is characteristic for the initial phases of technological product developments.

Using today's technology, a hybrid PV/Th system yields less energy than the sum of the separate components, i.e. the pv and solar thermal system. This energy reduction has not only resulted in much fundamental research (currently) being performed on the product / component level, but also in various system concepts being developed. Each system is characterised by different performances on energy, durability, building integration etc. Consequently, these concepts are hard to evaluate and compare from technological point of view, but also from the market point of view. Therefore, a simple methodology was developed to address the (future) technological and market perspectives of the various concepts.

2. EVALUATION METHOD

The methodology starts with the definition of the most important criteria to equally qualify promising hybrid PV/Th system. These criteria are listed in **Table 1**.

Table 1 : Evaluation criteria.

Criteria	(unit)
Time to market	yr
Market potential	m^2/jr
Investment	/m^2
Building integration	/m^2
Thermal Performance	GJ/yr·m^2
Electrical Performance	kWh_e/yr·m^2
Energy consumption	kWh_e/yr·m^2
Sustainable building	-
Life time	yr
Effect on energy performance	-

These ten criteria are used to validate eight ‘promising’ hybrid PV/Th systems. The PV/Th systems, result from ideas generated during the preceding literature survey and are defined and selected by a panel of experts. The proposed systems are believed to be the most promising systems using today’s technology, are applicable to moderate North West European climates and technically feasible within 5 to 10 years in new building projects.
The methodology has as a goal to show the real technological and market value of the defined systems.

3. EVALUATED HYBRID SYSTEMS

During the selection of the hybrid systems to be evaluated, emphasis is put on the match between supply and demand of electricity above heat. The following eight systems were assessed.

3.1 PV facade

Building integrated pv in façade offers a relatively simple opportunity to utilise the heat generated in the pv panels. In that case the pv façade acts as an unglazed PV/Th air collector and may supply natural ventilation in summer and pre-heated air in winter. In spring or summer either ventilation or pre-heated air may be supplied, depending of the climate. Applications are foreseen in industrial buildings (e.g. distribution centres), where heating and ventilation are hard to accomplish / have a low priority.

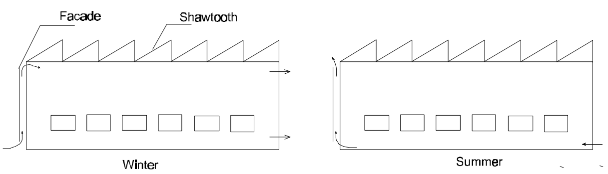

Figure 2: Unglazed PV/Th air collector as ventilated PV facade in an industrial building.

3.2 Biomass dryer

An unglazed PV/Th collector can be used to dry biomass (e.g. tulip bulbs and woodchips). Not all industrial drying processes can be utilised by solar energy due to the relatively low energy efficiency and low temperatures.

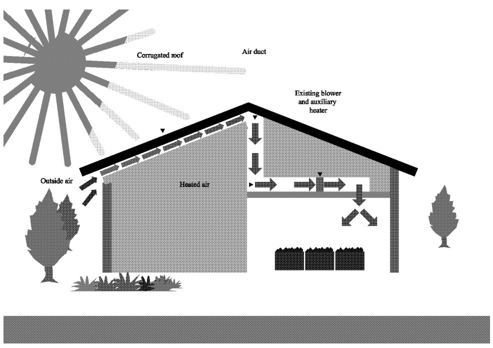

Figure 3: Unglazed PV/Th air collector for drying tulip bulbs.

3.3 Indoor swimming pool

To heat the water of an indoor swimming pool to max. 30 °C a simply covered PV/Th collector will suffice.

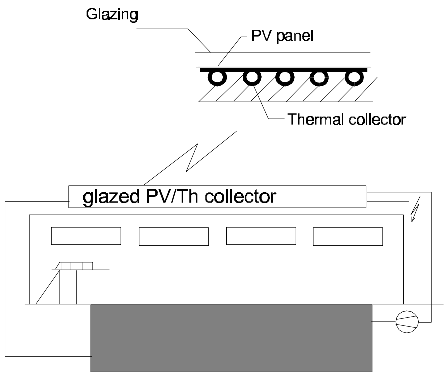

Figure 4: Glazed PV/Th water collector for pool heating.

3.4 In- and outdoor swimming pool.

An unglazed PV/Th collector can pre-heat the cold water supply (10 °C). During summer times, auxiliary heating is not necessary.

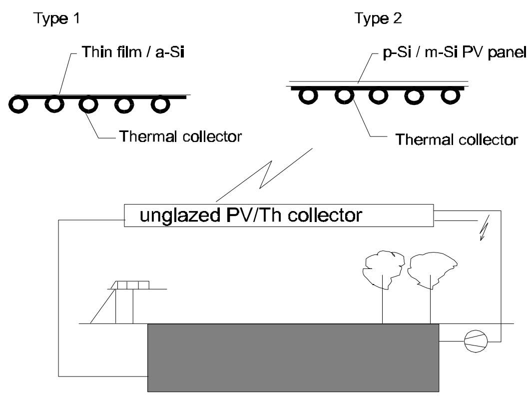

Figure 5: Unglazed PV/Th water collector for pool heating.

3.5 Heat pump I

The pre-heated air of the unglazed PV/Th collector supplies the heat pump of its heat source.

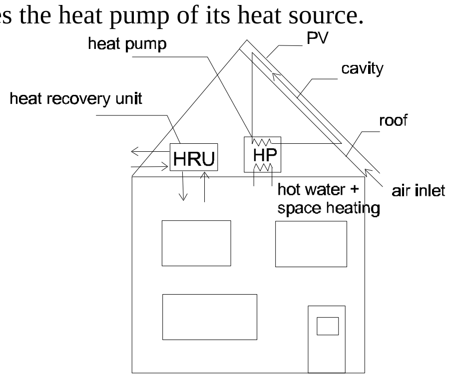

Figure 6: Unglazed PV/Th air collector combined with a heat pump and heat recovery unit.

The heat pump upgrades the pre-heated air to low temperature space heating. Additionally, a heat recovery unit is installed to reduce the heat losses. This system is demonstrated in Zwaag (NL) since 1998 [3].

3.6 Heat pump II

Here, an unglazed PV/Th collector is combined with a heat pump and aquifer. In summer, the PV/Th collector is cooled with 5~10°C from the aquifer. While cooling the PV/Th collector, the water is heated to about 20 °C, and stored in the aquifer to be used as heat source for the heat pump in winter. In winter, the heat pump upgrades the stored heat for low temperature space heating to about 40 °C. (During this process, the aquifer is fed with cold water 5~10 °C again).

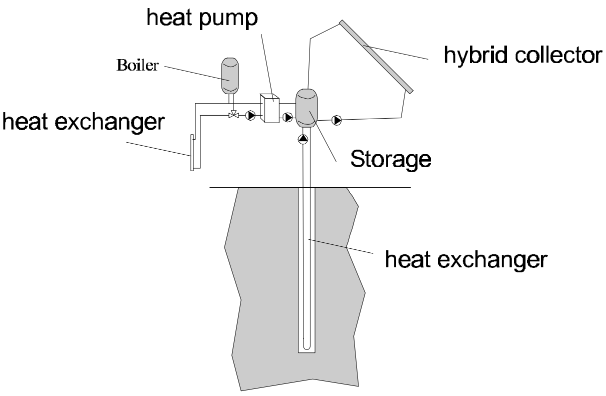

Figure 7: Unglazed PV/Th water collector combined with a heat pump and aquifer

This system offers opportunities to regenerate the heat in the soil when heat pumps are used on a large scale in urban areas and is now tested in practical conditions [4].

3.7 Solar hot water system

A glazed PV/Th collector combines directly the functions of pv (electricity) and a domestic hot water system (hot tap water). The pv panel acts as an absorber in the thermal collector.

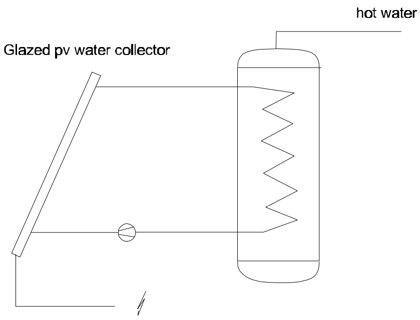

Figure 8: Glazed PV/Th water collector for tap water heating.

3.8 Solar hot water system & space heating

Identically as in the preceding paragraph, but now the PV/Th collector also supplies heat for space heating, meaning a larger roof area to be covered with PV/Th.

4. RESULTS

The above recalled systems were evaluated against the ten criteria mentioned in chapter 2. The effects of each criteria on each system was quantified for the Dutch circumstances. This resulted in an extended and quantified matrix: the upper row listing the systems; the left column, the ten criteria. Some highlights are listed here.

4.1 Market Potential

The research showed that the maximal possible market potential in The Netherlands is the largest for the heat pump systems (about $2{\cdot}10^6$ m²/yr). The second largest market potential exits at the solar water heaters (about $1{\cdot}10^6$ m²/yr)., followed by the pv facade (about $0.3{\cdot}10^6$ m²/yr). The swimming pool applications seem to be a nice “niche” market (about $2{\sim}7{\cdot}10^3$ m²/yr): investments are low, revenues relatively high thanks to the low operating temperature. Theoretically, all houses can be equipped with these type of systems, as such it must compete with other energy systems, also conventional gas-fired systems. The real market potential will thus be lower and depends on the demand.

4.2 Time to Market

Concerning the ‘time to market’, the PV/Th combination of PV and solar water heaters is most advanced. PV and solar water heaters are known technologies, each with their own market channels. Nowadays, some PV/Th systems are on the market, others are close to market introduction. Therefore, the time to market demonstration is 0, market introduction may follow in about 2 years time. During that time, experiences and learned lessons can be evaluated and processed. Perhaps, the same absorber can be used in unglazed systems like the swimming pool applications. The PV facade is also in the market introduction phase (e.g. Mataró building (Spain), JRC Ispra a-Si facade (Italy)). Performance data and cost / benefit analyses in different climates has to prove its validity. The time to market introduction is about 2 to 3 years. The heat pump systems are still in a (pre)mature development phase. The new technologies have to be tested and experimented (now under development in The Netherlands). The time to market demonstration and introduction for the heat pump systems will be the largest.

4.3 Simple Pay Out Time

Using the data on investment costs, saved materials, electrical and thermal revenues and its benefits, the simple pay out time (SPOT) of the various systems could be calculated (table 2 and 3) and compared to those of a traditional pv panel (table 4). This calculation is performed for both the p-Si and a-Si PV panels; cost estimation for the year 2000.

Table 2: Simple Pay Out Time (p-Si)

p-Si	PV facade	Biomass dryer	Swimming Pool In	Swimming Pool in & out
Costs (/m^2)	0 - 445	560	655	560
Electricity Saving (/m^2·yr)	5.5	1.5	7.5	8.5
Gas saving (/m^2·yr)	1.5	4	5	5.5
SPOT	0-64	102	52	40

p-Si	HP I (HRU)	HP II (soil)	DHW Tap water	DHW Tap & space
Costs (/m^2)	730	830	865	830
Electricity Saving (/m^2·yr)	8	8	7.5	7.5
Gas saving (/m^2·yr)	-	-	7	3.5
SPOT	-	-	60	75

Table 3: Simple Pay Out Time (a-Si)

a-Si	PV facade	Biomass dryer	Swimming Pool In	Swimming Pool in & out
Costs (/m^2)	220	420	515	425
Electricity Saving (/m^2·yr)	3	-2.5	4.5	5
Gas saving (/m^2·yr)	1.5	5	5.5	6
SPOT	49	170	52	39

a-Si	HP I (HRU)	HP II (soil)	DHW Tap water	DHW tap & space
Costs (/m^2)	590	645	680	645
Electricity Saving (/m^2·yr)	5	4.5	4.5	4
Gas saving (/m^2·yr)	-	-	7.5	4
SPOT	-	-	57	80

Table 4: Simple Pay Out Time (reference)

	Façade		Roof	
	p-Si*	a-Si**	p-Si	a-Si
BIPV (/m^2)	660	450	570	430
Yield (kWh/m^2·yr)	55	35	80	50
Benefit (/m^2·yr)	6	4	9	5.5
SPOT (yr)	110	110	65	80

*: 100 Wp/m^2 **: 60 Wp/m^2

5. CONCLUSIONS

From the technological perspective, PV/Th systems are especially suitable for low temperature applications (unglazed collectors in e.g. heat pump systems). For medium temperature applications, the thermal and electrical yield of the hybrid system is lower than that of the two separate systems. This is due to the very basic reason that the solar collector performs best by reaching high temperatures, whereas the pv panel reaches its' maximum yield at low temperatures. The combination of the two will always be a compromise. Hence, a hybrid system is economic viable, when the costs of the reduced energy performance matches the gained costs of production, installation and mounting. Apart from the economic motive, the uniform appearance of the PV/Th system may provide an important surplus value in terms of the enhanced architectural aesthetics.

The results on PV/Th systems, both on the product / component level (R&D) and the system level (demonstration) show sufficient prove to enhance the interests and possibilities of PV/Th systems.

The pv facade is marked by the shortest pay back time. This strongly depends, though, on the amount of material saved. Due to the high electricity consumption of the biomass dryer, this system has the longest pay back period. The pay back period of the heat pump systems could not be calculated as these systems yield heat which can not directly be used, a heat pump is required to supply the real energy demand. The glazed collectors in the domestic hot water systems do match the pay back period of single PV panels. It is marked though, that two separate systems (PV & Th) will be more economically viable by their higher energy efficiency. The unglazed PV/Th collector in swimming pools may be an attractive niche market.

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